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A Cyber foraging System for Resource Allocation in Emergency and Efficient Healthcare Service Delivery

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ABSTRACT
The appropriateness of mobile devices in emergency rescue operations cannot be over-emphasized, their computational capabilities can be harnessed as their weight, size and mobility support the nomadic nature of man. PDAs and smart phones come with moderate-sized processors that only make them available for limited computational purposes, These resource starved devices are now becoming useful tools for handling resource intensive computational problems through the concept of cyberforaging which is a mechanism that augments the computational and storage capabilities of mobile devices. In this paper, a cyberforaging-based resource allocation tool which can assist Incident managers in resource allocation and transportation for multiple simultaneous incidents was developed.

Keywords
clients, cyberforaging, emergency, resource allocation, surrogates.

1. INTRODUCTION
Cyberforagingis the use of computing capabilities of nearby servers (surrogates) via remote executionto augment the capabilities of mobile devices thereby providing portable mobile devices (clients) the ability to run demanding applications[1].

The appropriateness of mobile devices in emergency rescue operations cannot be over-emphasized, during multiple mass casualty incidents; the optimal deployment of emergency resources is a challenging task due to the competition for the limited available crucial resources [2]. In such situation of emergencies, health workers should be able to easily retrieve the patient health information, begin to give preliminary care, communicate with hospital and prepare the patient for treatment as they transfer him or her in an ambulance to the hospital through the World Wide Web (WWW) and use of mobile devices such as PDA, mobile phones, e.t.c[3]. While managing situations in emergencies, resource-intensive tasks may be encountered whose computational requirement exceeds the mobile device's capability, hence, such device could cyber forage by offloading heavy tasks to surrogates.Cyberforaging is of immense benefit in such scenarios because it combines the mobility of client devices and the high processing power of the surrogates [4]. In this paper, we present the application of a cyber foraging system to a hypothetical disaster scenario that involves the emergency allocation of hospital resources and patients based on their acuity level and nearness to hospital. This work also demonstrates the applicability of cyber foraging to the healthcare domain, a domain were not much have been done in the application of cyber foraging.

2. RELATED WORKS
Satyanarayanan[1] in his paper on the vision and challenges of pervasive computing laid the foundation of the concept of cyber foraging by using surrogates to support pervasive systems. Mads [5] developed a framework called LOCUSTS which aimed to provide developers with a complete cyber foraging toolbox that can ease the process of developing applications that utilize cyber foraging. Sachin and John [6] built a surrogate infrastructure based on virtual machine technology that allows resource-constrained devices to utilize a surrogate's compute, network, and storage resources. A major goal of their work was to support cyber foraging on a conventional platform, without a large middleware layer, and demonstrate its use on real applications and systems.
Illustrated in figure 1 is a simple cyber foraging scenario.

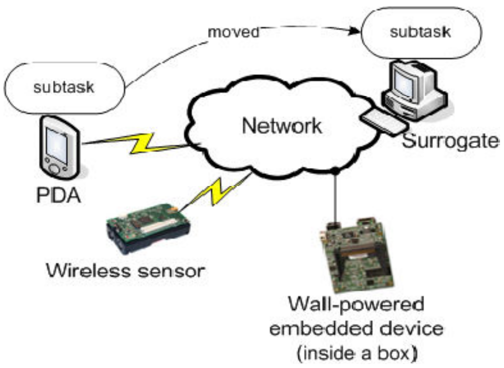

Figure 1: A cyber foraging scenario [6]

Ya-Yunn[7] also developed SLINGSHOT which uses remote computers located at wireless hotspots to execute application services on behalf of mobile computers. They explored how portable storage can improve the performance of a cyber foraginginfrastructure. Review of literature reports little or no application of cyber foraging in the medical domain, hence the relevance of this work.

3. SYSTEM FRAMEWORK
In this work, we developed a cyber foraging framework which was integrated into the health grid, the framework is shown in figure 2 and it comprises of:A local area network (LAN) of portable devices connected via IEEE 802.15.1, Surrogates (servers), Proxy (Internet gateway), healthcare center with health givers carrying their mobile devices and a computational grid.

4. MODEL IMPLEMENTATION

A cyberforaging model was implemented as an application for experimental purpose. The model is shown in figure 3 and it is a two-tier software application.The first runs on the server (surrogate) and it implement features such as: surrogate info transmission, service installation, service uninstallation and service execution.The second application runs on the mobile device and it implements features such as: surrogate discovery and service invocation/task offload.Both applications are called CyberForaging Server Library (CFSL) and CyberForaging Client Library (CFCL) respectively which can then communicate via the Communication Link Stack.

4.1 The Cyber-Foraging Server Library (CFSL)

This library serves as the platform for server applications that run on the Surrogate Server. It runs as a service and provides interfaces for starting Cyber-Foraging on a machine, responding to connections from the Cyber-Foraging clients to applications that uses it. It is composed of: the CyberForagingLib class and the communication link stack.

4.2 The Cyber-Foraging Client Library (CFCL)

This library serves as a platform for the mobile applications was developed using Java 2, micro edition (J2ME).

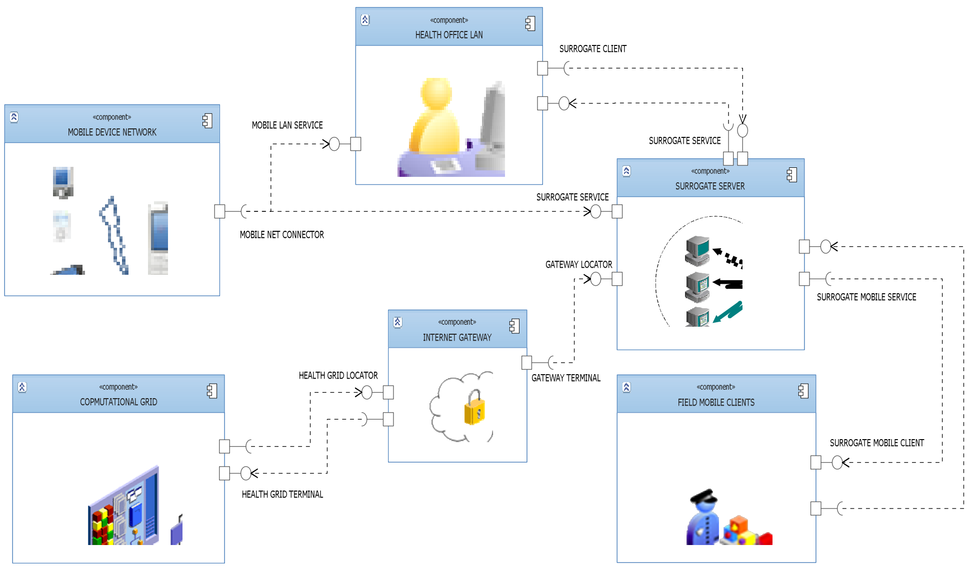

Fig 2: The Framework for integrating cyberforaging into the Healthgrid.

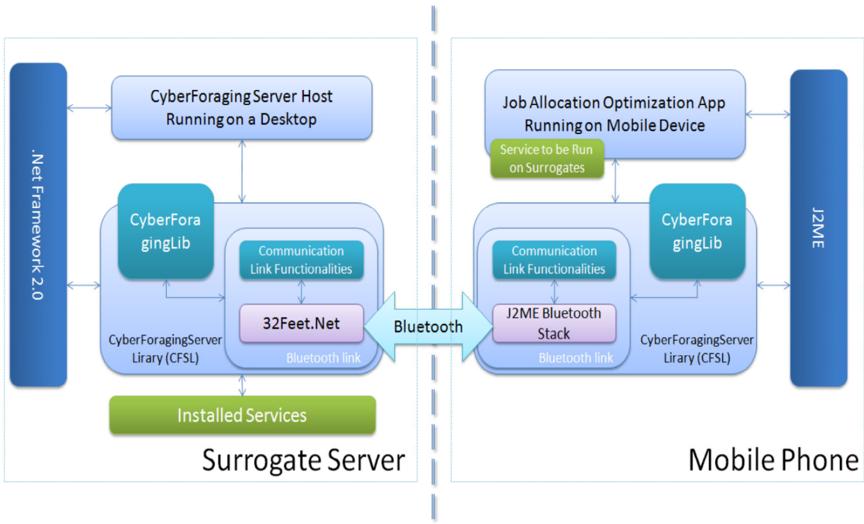

Fig 3: An Implementation view of the model

4.3The Communication Channel

Different communication technologies have been developed for both mobile devices and the desktop (remote) computers. Some of those technologies used by mobile phones include:Infra Red Link, Links provided by telecommunication providers such as GPRS, EDGE, etc. and Bluetooth Technology, these communication links are all capable of linking mobile phones to desktop PCs. However, the Bluetooth technology was adopted in this work as a considerable proportion of mobile phones and personal computers support bluetooth.

Server applications that use the CFSL register the communication links they support (these are picked from the Communication Link Stack). For example, a server application designed to run on a Computer that doesn't have a Bluetooth radio should obviously not register the Bluetooth Communication Link Object with the CFSL while a PC that does not have a WLAN NIC should not register the HTTP or Socket Communication Link.

5. COMPUTATIONAL EXPERIMENTATION

In order to validate the developed system, a hypothetical distaster scenario was taken from literature[2] for the purpose of experimentation.

The Problem: (Emergency Resource Allocation and Patient Acuity Dispatch)

Considering a disaster scenario with three (3) emergency sites and six (6) hospitals, with a number of casualities at each of the emergency sites. The estimated time taken to travel from hospitals to emergency sites, the number of the available beds at each hospital for each level of acuity (severity: red yellow, green) and theacuity levels of each victim are given on tables 1, 2 and 3 respectively. The problem here is to determine an optimal allocation of the available resources and the dispatch of victims based on their acuity level tonearest hospitals with the use of the mobile phone.

Table 1:Transport time matrix (in minutes)

Hospital	Emergency Site 1	Emergency Site 2	Emergency Site 3
1	29	6	34
2	31	13	28
3	21	27	33
4	26	28	9
5	22	27	34
6	37	35	28

Table 2: Available beds matrix

Hospital	Red	Yellow	Green
1	4	5	6
2	5	4	2
3	5	4	5
4	6	3	4
5	4	3	4
6	4	2	8

Table 3: Victims at each emergency site

Emergency Site	Red Victims	Yellow Victims	Green Victims
1	8	7	9
2	9	6	8
3	8	5	11

6. SYSTEM IMPLEMENTATION

The developed cyberforaging model was implemented with C# using client/server socket programming while Bluetooth was used for establishing the communication link. The system was modelled using UML, system flowcharts and algorithms are presented in the main research report. Figures 4 and 5 represent input screens of the mobile device (cyber system) establishing connection with the surrogate.

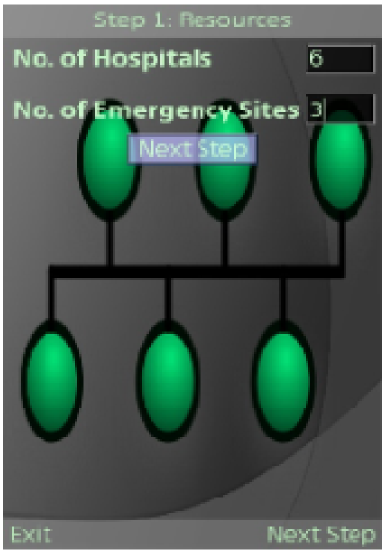

Fig. 4: Emergency Resource Allocation

Fig. 5:CF Client Bluetooth Connection Permission

The CFCL sends an Invoke service request to CFSL with the obtained parameters and waits for a reply, upon reception of the response, the CFCLimmediately initiates a Service Installation request to the CFSL. Figure 6 is the server side of the system showing service request invocation.

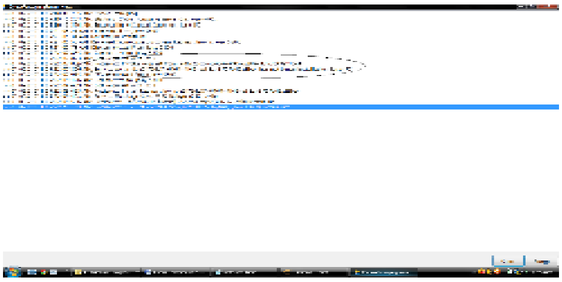

Figure 6: CFSL Receives and Processes Service Invoke request

6.1 Test Environment For The Mobile Application

The cyberforaging client application was tested on a Nokia 5800 XpressMusic phone and significant applications for the test phone are given below:

(i) RAM: 128MB
(ii) Internal (phone) memory: 81MB
(iii) Processor: ARM II 434MHz
(iv) Operating system: Symbian OS v9.4
(v) Java: Yes, MIDP 2.1, CLDC 1.1
(vi) Display size: 360 x 640 pixels, 3.2 inches
(vii) Bluetooth: Yes, v2.0 with A2DP (Nokia 5800 XpressMusic – Full phone specifications, 2011)

6.2 Test Environment For The Server Application

The cyberforaging server (surrogate) application was tested on a HP pavillon 620 laptop and the significant specifications for the test computer are listed below:

(i) RAM: 3GB
(ii) Processor: Intel Centrino Duo at 1.6GHz
(iii) Operating system: Windows 7
(iv) Primary monitor resolution: 1280 x 800
(v) Free space on hard disk: 3GB

7. RESULTS

After the implementation for the victim allocation system, the results obtained for the problem considered are shown in Figures 7a, b and c. These results shows optimal allocation of victims for the three (3) emergency sites. The results obtained are comparable with [1] which was a web-based system.

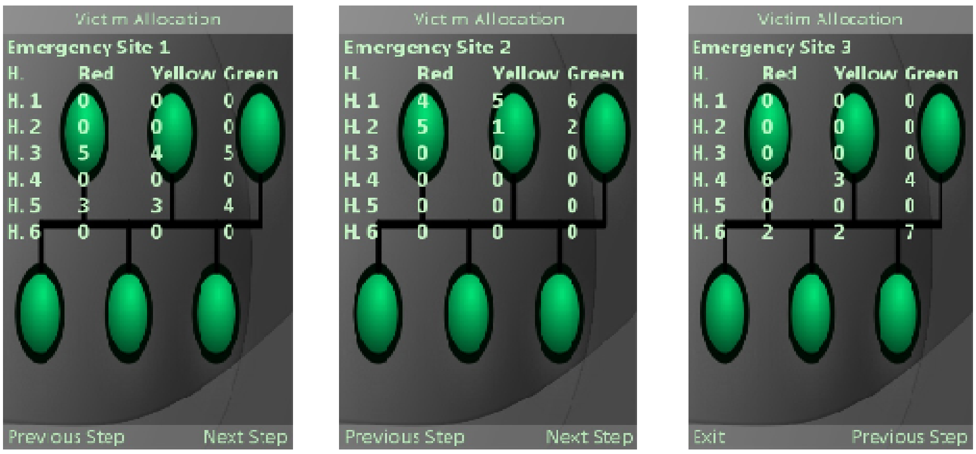

Figure 7(a)(b)(c): Result of computation for emergency sites 1, 2 and 3

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8. PERFORMANCE EVALUATION

In evaluating the performance of the system, the metrics usedare shown on tables 4.1 (a) and (b): Execution time: This is the time taken to solve the computational task from input to when result is being output.
Transfer time: time taken to offload the task from the mobile device to the surrogate.
Transfer rate: a measure of the volume of data transfer from the client to surrogate per unit of time.
Workload: Total average transfer time * 100/ Total duration.
In order to obtain data for the performance evaluation, thirty six (36) different scenarios consisting of a combination of different number of hospitals and emergency sites were randomly selected for experimentation. The 36 different scenarios were executed in two seperate iterations. For each scenario, and for each iteration, the execution time, transfer time, and total duration were captured and recorded. The time was measured in milliseconds. It was noticed that the execution time for most scenarios in the two iterations were different and so the difference was computed in column delta on table 4.1(b).

The average of the two execution time was obtained and the weight which is the sum of the number of hospital and number of emergency site which determines the degree of complexity of the permutation size was also computed. In order to eliminate bias in the weights an adjusted weight was computed.

Figure 8 is the graph showing the relationship between the problem scenarios and the transfer time, while figures 9 and 10show the execution time and the total time taken for each problem scenario for both local (client) and remote (surrogate).

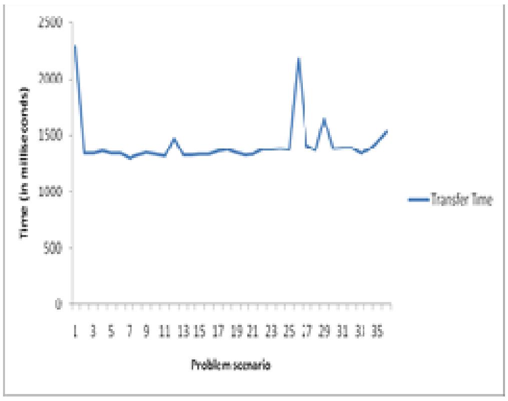

Fig. 8: Problem scenarios and transfer time

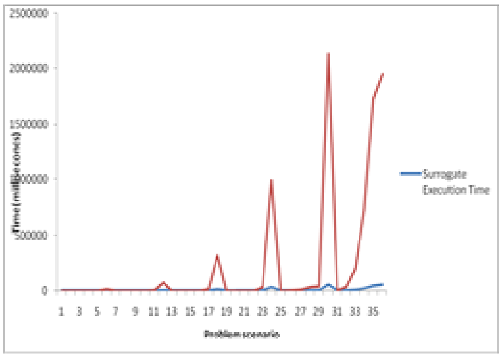

Fig. 9: local and surrogate execution time

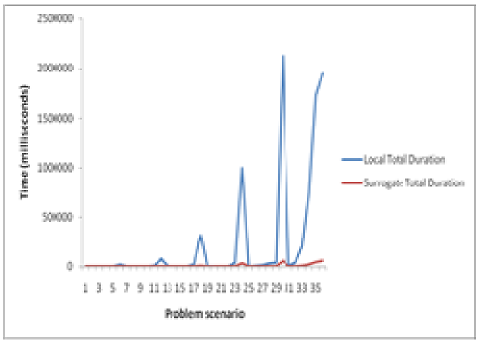

Fig. 10: Relationship between the total duration of local and surrogate

Table 4.1(a): Experimental data and evaluation metrics

	Scenario		Duration(Iteration 1) (ms)			Duration(Iteration 2)(ms)		
S/n	Hospitals	Sites	Execution time	Transfer time	Total duration	Execution time	Transfer time	Total Duration
1	2	2	779	2492	3271	769	2074	2843
2	2	3	867	1329	2196	778	1350	2128
3	2	4	700	1320	2020	886	1359	2245
4	2	5	705	1335	2040	731	1383	2114
5	2	6	846	1318	2164	1009	1361	2370

6	2	7	1955	1361	3316	2354	1311	3665
7	3	2	704	1304	2008	698	1288	1986
8	3	3	690	1340	2030	1034	1309	2343
9	3	4	910	1355	2265	704	1337	2041
10	3	5	730	1335	2065	730	1335	2065
11	3	6	953	1316	2269	977	1324	2301
12	3	7	3824	1359	5183	3917	1582	5499
13	4	2	713	1343	2056	789	1301	2090
14	4	3	688	1307	1995	715	1339	2054
15	4	4	784	1331	2115	889	1333	2222
16	4	5	720	1314	2034	748	1349	2097
17	4	6	1264	1319	2583	1506	1409	2915
18	4	7	10683	1384	12067	11630	1362	12992
19	5	2	700	1326	2026	889	1373	2262
20	5	3	748	1342	2090	800	1310	2110
21	5	4	777	1332	2109	788	1334	2122
22	5	5	811	1412	2223	761	1334	2095
23	5	6	2054	1363	3417	2294	1382	3676
24	5	7	30925	1458	32383	31800	1303	33103
25	6	2	1657	1421	3078	1501	1335	2836
26	6	3	1597	3007	4604	19973	1357	21330
27	6	4	2312	1493	3805	1251	1334	2585
28	6	5	2092	1384	3476	1730	1348	3078
29	6	6	2746	1385	4131	1994	1903	3897
30	6	7	59824	1420	61244	57861	1347	59208
31	7	2	1602	1369	2971	2015	1413	3428
32	7	3	2396	1478	3874	2361	1299	3660
33	7	4	6826	1333	8159	6602	1342	7944
34	7	5	21089	1365	22454	21441	1376	22817
35	7	6	48892	1520	50412	47497	1369	48866
36	7	7	58701	1643	60344	56786	1408	58194

Table 4.1(b): Experimental data and evaluation metrics

	Delta(Difference)			**Average**				
S/n	Execution time	Transfer time	Total duration	Execution time	Transfer time	Total duration	weight	Type
1	10	418	428	774	2283	3057	4	Equal
2	89	21	68	822.5	1339.5	2162	5	Lesser
3	186	39	225	793	1339.5	2132.5	6	Lesser
4	26	48	74	718	1359	2077	7	Lesser
5	163	43	206	927.5	1339.5	2267	8	Lesser
6	399	50	349	2154.5	1336	3490.5	9	Lesser
7	6	16	22	701	1296	1997	5	Greater
8	344	31	313	862	1324.5	2186.5	6	Equal
9	206	18	224	807	1346	2153	7	Lesser
10	0	0	0	730	1335	2065	8	Lesser
11	24	8	32	965	1320	2285	9	Lesser
12	93	223	316	3870.5	1470.5	5341	10	Lesser
13	76	42	34	751	1322	2073	6	Greater
14	27	32	59	701.5	1323	2024.5	7	Greater
15	105	2	107	836.5	1332	2168.5	8	Equal
16	28	35	63	734	1331.5	2065.5	9	Lesser
17	242	90	332	1385	1364	2749	10	Lesser
18	947	22	925	11156.5	1373	12529.5	11	Lesser
19	189	47	236	794.5	1349.5	2144	7	Greater
20	52	32	20	774	1326	2100	8	Greater
21	11	2	13	782.5	1333	2115.5	9	Greater
22	50	78	128	786	1373	2159	10	Equal
23	240	19	259	2174	1372.5	3546.5	11	Lesser
24	875	155	720	31362.5	1380.5	32743	12	Lesser
25	156	86	242	1579	1378	2957	8	Greater
26	18376	1650	16726	10785	2182	12967	9	Greater
27	1061	159	1220	1781.5	1413.5	3195	10	Greater
28	362	36	398	1911	1366	3277	11	Greater
29	752	518	234	2370	1644	4014	12	Equal
30	1963	73	2036	58842.5	1383.5	60226	13	Lesser

31	413	44	457	1808.5	1391	3199.5	9	Greater
32	35	179	214	2378.5	1388.5	3767	10	Greater
33	224	9	215	6714	1337.5	8051.5	11	Greater
34	352	11	363	21265	1370.5	22635.5	12	Greater
35	1395	151	1546	48194.5	1444.5	49639	13	Greater
36	1915	235	2150	57743.5	1525.5	59269	14	Equal

9. CONCLUSION

In this work, portable mobile devices such as PDAs and smart phones, which are naturally resource-starved were used to solve the resource allocation problem, through the concept of cyber foraging. This was achieved through the development of a model which allows the mobile device to communicate with surrogate server via bluetooth links. This has also helped to demonstrate the appropriateness of mobile devices in emergency rescue scenarios and resource allocation tasks thereby extending the use of mobile devices in the health care domain. Based on the foregoing, it is recommended that other communication protocols be explored as the data transfer rate and distance could limit connectivity using Bluetooth especially for large scale implementation.

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